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Interest Rate and Its Volatility Threshold on Stock Market Returns: Evidence from Ghana and South Africa

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Abstract:
This study argues that macroeconomic theory, which espouses a threshold, best explains the interest rate-return relation in emerging economies. Consequently, it develops a quantile regression model with nonlinear variables to examine this, with a focus on Ghana and South Africa. The threshold interest rate for the former country, 25.7 percent, significantly exceeds that of the latter, 6.84 percent. Furthermore, the nonlinear interest rate component raises returns in Ghana. In South Africa, interest rate volatility increases returns. Also, there is a direct interest rate-return interaction in Ghana. At lower quantiles, however, the interest rate volatility-return interaction erodes returns in both countries.
Keywords: interest rate-return threshold, interest rate volatility, quantile regressions, nonlinear model.
JEL classification: C31, E44, G12.

1. Introduction

Interest rates are a key monetary policy tool affected by external and internal economic conditions. As a critical component of cost of capital, they are pivotal to expanded economic activity, production and output. Further, interest rates affect financing and related costs. This adversely affects cash flows, income and future prospects of firms, all of which are a major component of stock market returns (Uddin & Alam, 2009).

Theoretically, interest rates adversely affect stock market returns. A variety of theories are offered to explain this. Firstly, the present value model argues that a rising interest rate decreases the current worth of expected cash flows of financial instruments (Humpe and Macmillan, 2009). Macroeconomic theory, on the other hand, argues that low stable interest rates encourage further direct investments and vice versa (Adam & Tweneboah, 2008). The capital asset pricing model (CAPM) intimates that market return is a function of the risk-free rate and sensitivity of stocks to market risk (Sharpe, 1964). The arbitrage pricing model (APT), however, postulates that market return is determined by multiple factors (Ross, 1976). It is not as restrictive as the CAPM. Fama (1981) espouses the proxy hypothesis, which states that interest rates are a substitute for underlying inflation. The substitution effect, developed by Jefferis & Okeahalam (2000), explains that interest-bearing assets are most preferred when interest rates rise.

On the one hand, some empirical studies find an inverse interest rate-stock market return relation (Arango, Gonzales & Posada, 2002; Fama, 1981; Huang, Mollick & Nguyen, 2016; Jefferis & Okeahalam, 2000; Zordan, 2005). However, Asamoah, Agana & Sakyi (2016), Mahmudul & Salah (2009), Ologunde, Elumilade & Asaolu (2006) and Uddin & Alam (2009) find a positive relation between the considered variables, mostly in developing and emerging economies. Convergence among advanced economies supports their common negative interest-return effect, while macroeconomic divergence among developing and emerging markets may explain their disparate interest rate-return nexus (Dani, 2011; Strazicich, Lee & Day, 2002). Despite this, there are few or no studies that explain why this mixed empirical evidence. Further, there is no consensus on the appropriate theory that explains the interest rate-return relation among developing and emerging economies.

The research problem herein is multi-pronged. Firstly, this study tests whether there is an interest rate threshold for stock market returns, as suggested by macroeconomic theory. This is to explain the mixed empirical evidence among emerging economies. As well, the study addresses the literature gap on such research in Sub-Saharan Africa (SSA), especially for these two countries. Additionally, it identifies the threshold interest rate in the examined economies. Also, it considers nonlinear and interactive influences of interest rate and its volatility on market returns.

The study focuses on two Sub-Saharan African (SSA) economies, namely: Ghana and South Africa. These are represented by the Ghana Stock Exchange (GSE) and Johannesburg Stock Exchange (JSE) of South Africa. The JSE is the largest as well as most active, efficient and liquid SSA stock market (African Securities Exchange Association, 2016; Asongu, 2013). At the other extreme, the GSE is relatively illiquid and inefficient

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(Ayentimi, Mensah & Naa-Idar, 2013). To achieve its purposes, this study begins with an introduction and literature review. This is followed by an explication of the methodological approach and data. The third chapter reports the analytical results and discusses the findings. The final section concludes.

2. Analytical framework, data and methodology

The underpinning framework is a variation of the APT. Let $r_{m,t}$ and i_{t-1} be the real market return at time *t* and interest rate at time *t-1* respectively. σ^i_{t-1} is interest rate volatility or risk at *t-1*.

$$r_{m,t} = i_{t-1} + \sigma^i_{t-1} \quad (1)$$

Equation (1) is a linear representation of the interest rate-return relation. It is, however, limited because it ignores nonlinear effects (Sorin, Pascu & Morariu, 2008). Therefore, (1 - $e^{i_{t-1}}$) is the nonlinear transformation of $r_{m,t}$, similar to Arango *et al.* (2002). $i_{t-1} * \hat{r}^{\pi}_{m,t}$ denotes interaction between i_{t-1} and $r_{m,t}$ while $\hat{\sigma}^i_{t-1} * \hat{r}^{\pi}_{m,t}$ is the interactive effect between σ^i_{t-1} and $r_{m,t}$.

$$r_{m,t} = i_{t-1} + \sigma^i_{t-1} + (1 - e^{i_{t-1}}) + (i_{t-1} * r_{m,t}) + (\sigma^i_{t-1} * r_{m,t}) \quad (2)$$

Equation (2) replaces (1) to take into account the nonlinear relations between interest rate, its volatility and stock market return. In line with Enders (2008), Focardi & Fabozzi (2004) and Greene (2011), all variables are normalized by the logarithm of return in order to ameliorate potential time-series anomalies, such as autocorrelation. Therefore, $r_{m,t}$, i_{t-1} and σ^i_{t-1} are transformed to $\gamma_{m,t}$, ν_{t-1} and ψ_{t-1} respectively. Also, (1 - $e^{i_{t-1}}$), ($i_{t-1} * r_{m,t}$) and ($\sigma^i_{t-1} * r_{m,t}$) are replaced by χ_{t-1}, κ_{t-1} and ϑ_{t-1} in turn. Equation (2) becomes (3):

$$\gamma_{m,t} = \nu_{t-1} + \psi_{t-1} + \chi_{t-1} + \kappa_{t-1} + \vartheta_{t-1} \quad (3)$$

A variety of methods were used in related threshold studies. One of these is the threshold autoregressive regression (TAR) approach (Tsay, 1989). Related to it is the smooth-transition autoregressive model (STAR), used by Dellaportas, Denison & Holmes (2007). The threshold vector error correction model (TECM) is another associated methodology (Krishnakumar & Neto, 2011). Departing from the TAR, STAR and TECM frameworks, there are other methodologies used, including diffusion processes with jumps (Mancini & Reno, 2010).

Quantile regressions, however, enable in-depth analysis of how the regressand responds to variations in regressors within different ranges. As well, it may be used for multiple threshold analysis. It also overcomes the weakness of standard linear regressions, whose computed parameters and single fitted line are severely affected by outliers (Boako, Omane-Adjepong & Frimpong, 2016; Gujarati, 2009; Greene, 2011; Koenker, 2005; Koenker & Hallock, 2001; Koenker & Xiao, 2002; Kuan, Michalopoulos & Xiao, 2016; Northrop, 2013).

Let τ and τ^* denote the τ th quantile and its threshold equivalent, respectively. Further assume that, $\tau \cup \tau^* \in T$. However, when $\tau < \tau^*$, returns are positively influenced by interest rate and vice versa. The associated quantile regression model, $Q(\tau^{\text{th}})$ or $\gamma^{\tau}_{m,t}$, is:

$$Q(\tau^{\text{th}}) = \gamma^{\tau}_{m,t} = \beta^{\tau}_{\nu} X^{\tau}_{\nu,t-1} + \beta^{\tau}_{\psi} X^{\tau}_{\psi,t-1} + \beta^{\tau}_{\chi} X^{\tau}_{\chi,t-1} + \beta^{\tau}_{\kappa} X^{\tau}_{\kappa,t-1} + \beta^{\tau}_{\vartheta} X^{\tau}_{\vartheta,t-1} + \varepsilon^{\tau}_{t} \quad (4)$$

In equation (4), β^{τ}_{ν}, β^{τ}_{ψ}, β^{τ}_{χ}, β^{τ}_{κ} and β^{τ}_{ϑ} are the regression coefficients of ν_{t-1}, ψ_{t-1}, χ_{t-1}, κ_{t-1} and ϑ_{t-1} respectively. $X^{\tau}_{\nu,t-1}$, $X^{\tau}_{\psi,t-1}$, $X^{\tau}_{\chi,t-1}$, $X^{\tau}_{\kappa,t-1}$ and $X^{\tau}_{\vartheta,t-1}$ are observations of respective independent variables, namely: interest rate, interest volatility, nonlinear interest, interest-return interaction and interest volatility-return interaction. ε^{τ}_{t} is the error term. The dependent variable is stock market return, $\gamma^{\tau}_{m,t}$. Adapting Boako *et al.* (2016) and Fang *et al.* (2007), the examined quantiles are the 10th, 25th, 40th, 50th, 60th, 75th and 90th. In line with the underlying research objective, the initial null and alternative hypotheses test whether, β^{τ}_{j}, the τ th quantile regression coefficients of variable *j* are non-equal. The second null, H^2_0, and alternative hypotheses, H^2_a, examine whether independent variables below their respective threshold increase returns. The opposite premise is evaluated by H^3_0 and H^3_a, posited in equation (5).

$$H^2_0: \beta^{\tau}_{j} = 0 \ \forall \ \tau < \tau^* \text{ and } H^2_a: \beta^{\tau}_{j} > 0 \ \forall \ \tau < \tau^* \ ; j:\{j \in \nu^{\tau}_{t-1}, \psi^{\tau}_{t-1}, \chi^{\tau}_{t-1}, \kappa^{\tau}_{t-1}, \vartheta^{\tau}_{t-1}\} \quad (5)$$

H_0^3: $\beta_j^\tau = 0 \ \forall \ \tau > \tau^*$ and H_a^3: $\beta_j^\tau < 0 \ \forall \ \tau > \tau^*$; j:{$j \in \nu_{t-1}^\tau, \psi_{t-1}^\tau, \chi_{t-1}^\tau, \kappa_{t-1}^\tau, \vartheta_{t-1}^\tau$}

Each quantile regression minimizes a weighted sum of absolute errors. However, the weights are determined by the considered quantile. ε^τ is an indicator process: $I(\varepsilon^\tau) \in \{1, 0\}$. It is worth noting that $I(\varepsilon^\tau)$ = 1 if $\varepsilon^\tau < 0$ and $I(\varepsilon^\tau) = 0$, when ε^τ has alternate values. $\delta_\varepsilon^\tau(\varepsilon)$, the error function, is posited as ε $(\tau - I(\varepsilon < 0))$. The relevant error minimization problem is:

$$\min_{x_t^j \ldots} \sum_{\tau=1}^{T} \delta_\varepsilon^\tau (\gamma_{m,t}^\tau - \beta_\nu^\tau X_{\nu,t-1}^\tau - \beta_\psi^\tau X_{\psi,t-1}^\tau - \beta_\chi^\tau X_{\chi,t-1}^\tau - \beta_\kappa^\tau X_{\kappa,t-1}^\tau - \beta_\vartheta^\tau X_{\vartheta,t-1}^\tau) \quad \forall \ \tau \in T \qquad (6)$$

Further assume that $s_{\tau,j}^2$ is the standard error of β_j^τ, while n_τ^j is the number of observations of variable j in the τ th quantile. Then, according to Chen & Wei (2005), Greene (2011) and Hansen (1999), the relevant sample coefficient homogeneity test for j has the general form for the examined quantiles is:

$$t_i = \frac{[(\hat{\beta}_1^{10th} - \hat{\beta}_1^{25th}) - (\beta_1^{10th} - \beta_1^{25th})] + \ldots\ldots\ldots\ldots\ldots\ldots + [(\hat{\beta}_1^{10th} - \hat{\beta}_1^{N}) - (\beta_1^{10th} - \beta_1^{N})]}{\left(\frac{s_{10th}^2}{n_{10th}} + \frac{s_{25th}^2}{n_{25th}} + \ldots\ldots\ldots + \frac{s_N^2}{n_N}\right)} \qquad (7)$$

The accompanying degrees of freedom (*df*) is:

$$df_i = \frac{\left(\frac{s_{10th}^2}{n_{10th}} + \frac{s_{20th}^2}{n_{22th}} + \ldots\ldots\ldots\ldots + \frac{s_N^2}{n_N}\right)^2}{\left(\frac{(s_{10th}^2 / n_{10th})^2}{n_{10th}} + \frac{(s_{25th}^2 / n_{25th})^2}{n_{25th}} + \ldots\ldots\ldots + \frac{(s_N^2 / n_N)^2}{n_N}\right)} \qquad (8)$$

4. Analysis, results and findings

The Treasury bill rate (TBR) is the representative interest rate used herein, similar to Asamoah *et al.* (2016) and Olweny & Omondi (2011). It is relatively market-determined and not as heavily subjected to central bank policy as the prime rate. Monthly time series data on the GSE all-share index and the related TBR are obtained from Bank of Ghana (2016). Similar information on South Africa is gathered from South African Reserve Bank (2016). Each dataset covers January 2002 to July 2016. The nonlinear and interaction variables are computed from the raw variables as defined in equation (3).

4.1 Pre-regression diagnostic tests

i. Causality test:

Tables 1 and 2 present the pairwise Granger causality tests for Ghana and South Africa respectively. For Ghana and South Africa, stock market returns do not Granger cause any independent variable and vice versa. Additional exogeneity tests, in table 2 for the two countries, involve returns regressed on each independent variable. For each country, the respective F-statistics are insignificant and the adjusted r-squareds are close to zero. These results imply that, for Ghana and South Africa, the independent variables are weakly exogenous to return.

Table 1: Pairwise Granger-causality asymptotic tests - Ghana

Variables	F-statistic (asymptotic test)	Degrees of freedom	Null hypothesis	P-value
Interest rate	0.13	F (2, 172)	H_0 : Stock market return does not granger cause interest rate	0.88
	0.27	F (2, 174)	H_0 : Interest rate does not granger cause stock market return	0.77
Nonlinear interest rate	0.003	F (2, 174)	H_0 : Stock market return does not granger cause nonlinear interest rate	0.99
	0.19	F (2, 174)	H_0 : Nonlinear interest rate does not granger cause stock market return	0.83
Interest rate volatility	1.76	F (2, 175)	H_0 : Stock market return does not granger cause interest rate volatility	0.17
	0.11	F (2, 175)	H_0 : Interest rate volatility does not granger cause stock market return	0.90
Interest rate-return interaction	2.87	F (2, 175)	H_0 : Stock market return does not granger cause interest rate-return interaction	0.59
	0.69	F (2, 175)	H_0 : Interest rate-return interaction does not granger cause stock market return	0.50
Interest volatility-return interaction	2.91	F (2, 175)	H_0 : Stock market return does not granger cause interest volatility-return interaction	0.57
	0.10	F (2, 175)	H_0 : Interest volatility-return interaction does not granger cause stock market return	0.90

Table 3: Pairwise Granger-causality asymptotic tests – South Africa

Variables	F-statistic (asymptotic test)	Degrees of freedom	Null hypothesis	P-value
Interest rate	0.69	F (2, 175)	H_0: Stock market return does not granger cause interest rate	0.50
	2.91	F (2, 175)	H_0: Interest rate does not granger cause stock market return	0.06
Nonlinear interest rate	0.11	F (2, 174)	H_0: Stock market return does not granger cause nonlinear interest rate	0.89
	1.58	F (2, 174)	H_0: Nonlinear interest rate does not granger cause stock market return	0.21
Interest rate volatility	0.36	F (2, 175)	H_0: Stock market return does not granger cause interest rate volatility	0.70
	1.91	F (2, 175)	H_0: Interest rate volatility does not granger cause stock market return	0.15
Interest rate-return interaction	2.83	F (2, 175)	H_0: Stock market return does not granger cause interest rate-return interaction	0.06
	1.76	F (2, 175)	H_0: Interest rate-return interaction does not granger cause stock market return	0.18
Interest volatility-return interaction	1.15	F (2, 175)	H_0: Stock market return does not granger cause interest rate volatility-return interaction	0.32
	0.54	F (2, 175)	H_0: Interest rate volatility-return interaction does not granger cause stock market return	0.59

Table 3: Additional exogeneity test

Dependent variable	Independent variable	F-statistic	P-value	Adjusted r-squared
	GHANA			
Interest rate	Market return 1.04	0.65	0.42	-0.00
Non-linear interest rate	Market return 1.04	0.14	0.71	-0.00
Interest rate volatility	Market return 1.03	0.07	0.79	-0.01
Interest-return interaction effect	Market return	3.59	0.06	0.01
Interest volatility-return interaction effect	Market return	3.09	0.30	0.02
	SOUTH AFRICA			
Interest rate	Market return	0.04	0.84	-0.01
Nonlinear interest rate	Market return	0.73	0.39	-0.002
Interest rate volatility	Market return	0.03	0.86	-0.01
Interest-return interaction effect	Market return	1.43	0.23	0.00
Interest volatility-return interaction effect	Market return	0.16	0.13	-0.00

ii. Multi-collinearity test:

The following pertinent multi-collinearity test indicators are computed for each country: condition index, eigenvalue, r-squared, tolerance factors and variance inflation factors (VIFs). These are presented in table 4. For both countries, all the VIFs are between 0.10 and 10. This means that they are not multi-collinear (Belsley, Kuh & Welsch, 2004; Greene, 2011; Gujarati, 2009). The other test statistics also indicate that there is no multi-collinearity.

Table 4: Multi-collinearity tests: r-squared, tolerance factors, VIFs

Variable	VIF	VIF square root	Tolerance factor	R-squared	Eigen-value	Condition index
GHANA						
Interest rate	1.46	1.21	0.68	0.32	2.79	1.00
Nonlinear interest rate	1.01	1.03	0.95	0.05	2.25	1.00
Interest rate volatility	1.12	1.06	0.89	0.11	0.96	1.52
Interest rate-return interaction	1.36	1.16	0.74	0.26	0.45	2.25
Interest volatility-return interaction	1.39	1.18	0.72	0.28	0.75	1.74
Stock market return	1.00	1.00	0.99	0.00	2.05	1.00
SOUTH AFRICA						
Interest rate	2.00	1.42	0.50	0.50	1.51	1.45
Nonlinear interest rate	2.09	1.44	0.48	0.52	1.04	1.80
Interest rate volatility	1.14	1.07	0.88	0.12	0.61	2.32
Interest rate-return interaction	1.10	1.05	0.91	0.09	0.32	3.21
Interest volatility-return interaction	1.87	1.37	0.54	0.47	0.15	4.65
Stock market return	1.78	1.34	0.56	0.44	3.28	1.00

iii. Stationarity test:

The augmented Dickey-Fuller (ADF) and Philips-Perron (PP) tests statistics are reported in table 5. The underlying hypothesis of these tests is that the examined variables are non-stationary. The results indicate that the relevant variables for Ghana and SA are stationary of the first order, I(1).

Table 5: ADF and PP test statistics (first-differenced variables)

Variables	Number of observations	ADF test statistic Z(t)	PP test statistic Z(t)	1% critical value	5% critical value	McKinnon P-value of test statistic
GHANA						
Interest rate	172	-9.166	-9.33	-3.482	-2.884	0.000
Nonlinear interest rate	172	-3.062	-5.99	-3.482	-2.884	0.029
Interest rate volatility	172	-4.308	-4.49	-3.482	-2.884	0.000
Interest-return interaction effect	172	-5.664	-18.31	-3.482	-2.884	0.000
Interest volatility-return interaction effect	172	-15.23	-13.86	-3.482	-2.884	0.000
Stock market return	172	-10.59	-10.74	-3.482	-2.884	0.000
SOUTH AFRICA						
Interest rate	172	-11.77	-11.71	-3.482	-2.884	0.000
Nonlinear interest rate	172	-3.19	-3.51	-3.482	-2.884	0.020
Interest rate volatility	168	-3.94	-3.97	-3.482	-2.884	0.000
Interest-return interaction effect	172	-12.85	-12.81	-3.482	-2.884	0.000
Interest volatility-return interaction effect	172	-13.81	-13.94	-3.482	-2.884	0.000
Stock market return	171	-14.24	-14.15	-3.482	-2.884	0.000

iv. Structural breaks:

There are breaks in the interest rates and stock market returns for both countries within the considered time period (Babikir, Gupta, Mwabutwa & Owusu-Sekyere. 2012; Boako *et al.,* 2016; Kyereboah-Coleman & Agyire-Tettey, 2008; Su, Chang & Liu. 2013). However, the afore-mentioned studies indicate that such breaks do not significantly affect the rigor and validity of related empirical analysis where the time-series has large observations and is stationary. The latter property implies that the variables are mean reverting (Enders, 2008; Greene, 2011).

4.2 Empirical analysis:

Tables 6 and 7 present the empirical results for Ghana and South Africa respectively. At low interest rates in 10th, 25th and 40th quantiles, the interest-stock return relation is positive for Ghana. For South Africa, this occurs at the 10th and 50th quantiles. This is reversed at higher interest rates / quantiles for both countries. The threshold interest rate for Ghana and South Africa are 25.7 and 6.84 percent respectively. These results confirm that low interest rates stimulate stock returns and vice versa (Kandir 2008; Olweny & Omondi, 2011). Ghana's upper threshold may be due to its extenuating economic environment, risk premiums and transaction costs (Aboagye & Akoena, 2008). This result emphasizes relative macroeconomic divergence between SSA countries (Maruping,2005). Additionally, South Africa's interest rate regression coefficient is larger than Ghana's. This may result from the GSE's inefficiency, which dampens stock return sensitivity to interest rate changes (Ayentimi *et al.*, 2013). Additionally, this result confirms a key conclusion of macroeconomic theory that interest has opposite effects on stock market returns at different extremes (Arango *et al.,* 2002*;* Asamoah *et al.,* 2016).

Overall, the nonlinear component of interest rates positively influences stock returns in Ghana. The same phenomena occurs in the 90th quantile for South Africa. These results confirm Arango *et al.* (2002). Interest rate volatility, however, has no effect on stock market returns in Ghana, contrasting the results of Muktadir-Al-Mukit (2013). On the other hand, the interest rate volatility-return interaction is positive in South Africa. This suggests that because of the GSE's inefficiency, the nonlinear element of interest rate may be the perceived risk indicator instead of interest rate volatility in Ghana (Tei Mensah, Adom & Pomaa-Berko, 2014). The JSE's efficiency enables it to respond to interest rate volatility and extremely high nonlinear interest.

In Ghana, the interaction between interest rate and market return positively affects the latter in all quantiles. No such result is found for South Africa. The interest rate volatility-return interaction adversely affects market returns at the 10th and 25th quantiles in South Africa and Ghana respectively. However, at higher quantiles, there is a direct influence. These may be because at lower quantiles, their impact can be estimated as part of transaction costs. However, at higher extremes, such interaction effects may be more difficult to quantify, perhaps leading to their direct inclusion as part of required returns.

Table 8 presents critical regression indicators for both countries. For Ghana, the adjusted r-squareds are relatively lower, all less than 16 percent. The same indicator for South Africa is greater than 50 percent in all quantiles. Additionally, South Africa's regression coefficients are larger, implying that interest rate changes are highly reflected in market returns. Therefore, variations in JSE returns are better explained by the posited model.

Table 6: Quantile regression results – Ghana

Variables	**Coefficient**	**Standard error**	**Z-statistic**	**P-value**
10th quantile				
Interest rate	0.003	0.001	-4.11	0.000
Nonlinear interest rate	0.00	0.00	5.68	0.000
Interest rate volatility	0.00	0.01	0.12	0.908
Interest-return interaction effect	0.03	0.01	3.85	0.000
Interest volatility-return interaction effect	-0.00	0.003	-0.16	0.876
25th quantile				
Interest rate	0.001	0.00	-4.35	0.000
Nonlinear interest rate	0.00	0.00	-2.89	0.004
Interest rate volatility	-0.003	0.003	-1.16	0.248
Interest-return interaction effect	0.02	0.01	4.34	0.000
Interest volatility-return interaction effect	-0.0002	0.00	-2.24	0.026
40th quantile				
Interest rate	-0.000	0.0002	-2.33	0.020
Nonlinear interest rate	0.00	0.00	-1.66	0.098
Interest rate volatility	-0.003	0.002	-1.11	0.270
Interest-return interaction effect	0.02	0.01	4.53	0.000
Interest volatility-return interaction effect	0.00	0.00	-0.69	0.486
50th quantile				
Interest rate	0.0002	0.0002	-1.32	0.188
Nonlinear interest rate	0.0000	0.00	-0.96	0.341
Interest rate volatility	-0.0020	0.002	-0.84	0.405
Interest-return interaction effect	0.0200	0.005	4.42	0.000
Interest volatility-return interaction effect	0.0000	0.00	-0.14	0.888
60th quantile				
Interest rate	0.00	0.0002	0.57	0.569
Nonlinear interest rate	0.00	0.00	-0.01	0.995
Interest rate volatility	-0.002	0.002	-0.93	0.35
Interest-return interaction effect	0.02	0.005	4.13	0.000
Interest volatility-return interaction effect	0.00	0.00	0.68	0.497
75th quantile				
Interest rate	-0.001	0.0003	2.54	0.012
Nonlinear interest rate	0.00	0.00	1.97	0.050
Interest rate volatility	-0.003	0.002	-1.27	0.204
Interest-return interaction effect	0.03	0.005	4.88	0.000
Interest volatility-return interaction effect	0.0001	0.00	2.17	0.031
90th quantile				
Interest rate	-0.002	0.001	4.41	0.000
Nonlinear interest rate	0.00	0.00	4.48	0.000
Interest rate volatility	-0.002	0.006	-0.29	0.772
Interest-return interaction effect	0.025	0.003	7.41	0.000
Interest volatility-return interaction effect	0.0003	0.0002	1.68	0.094

Table 7: Quantile regression results - SA

Variables	Coefficient	Standard error	Z-statistic	P-value
10th quantile				
Interest rate	0.30	0.15	-2.05	0.04
Nonlinear interest rate	-0.00	0.00	-1.78	0.08
Interest rate volatility	1.32	0.09	14.5	0.00
Interest-return interaction effect	0.05	0.06	0.81	0.42
Interest volatility-return interaction effect	-2.33	1.06	-2.19	0.03
25th quantile				
Interest rate	0.07	0.16	0.44	0.70
Nonlinear interest rate	0.00	0.00	0.29	0.77
Interest rate volatility	1.73	0.16	10.99	0.00
Interest-return interaction effect	-0.21	0.16	-1.32	0.19
Interest volatility-return interaction effect	-2.02	1.73	-1.17	0.24
40th quantile				
Interest rate	0.15	0.10	1.47	0.14
Nonlinear interest rate	0.00	0.00	1.21	0.23
Interest rate volatility	1.86	0.19	10.04	0.00
Interest-return interaction effect	-0.87	0.17	-0.51	0.61
Interest volatility-return interaction effect	-1.46	0.97	-1.50	0.14
50th quantile				
Interest rate	0.22	0.11	2.05	0.04
Nonlinear interest rate	0.00	0.00	1.45	0.15
Interest rate volatility	1.85	0.20	9.42	0.00
Interest-return interaction effect	-0.08	0.17	-0.44	0.70
Interest volatility-return interaction effect	-1.50	0.99	-1.52	0.13
60th quantile				
Interest rate	-0.26	0.11	2.44	0.02
Nonlinear interest rate	0.00	0.00	1.78	0.08
Interest rate volatility	1.89	0.19	10.05	0.00
Interest-return interaction effect	0.00	0.16	0.00	0.99
Interest volatility-return interaction effect	-1.48	0.96	-1.54	0.13
75th quantile				
Interest rate	0.28	0.18	1.52	0.13
Nonlinear interest rate	0.00	0.00	1.77	0.08
Interest rate volatility	1.73	0.15	11.19	0.00
Interest-return interaction effect	-0.03	0.14	-0.26	0.80
Interest volatility-return interaction effect	0.15	2.11	0.07	0.94
90th quantile				
Interest rate	0.34	0.20	1.68	0.09
Nonlinear interest rate	0.00	0.00	4.23	0.00
Interest rate volatility	1.88	0.18	10.73	0.00
Interest-return interaction effect	-0.11	0.11	-0.98	0.33
Interest volatility-return interaction effect	2.70	2.07	1.28	0.20

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Table 8: Quantile regression diagnostics – Ghana and South Africa

INDICATOR	10th	25th	40th	50th	60th	75th	90th
GHANA							
Adjusted r-squared	0.13	0.14	0.14	0.12	0.15	0.13	0.12
F-statistic	19.58	20.84	19.80	23.81	20.91	25.09	21.45
P-value (F-statistic)	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Ramsey test (H_0 : no omitted variables)	1.39	1.05	0.97	0.67	0.29	1.12	0.82
P-value of Ramsey test	0.67	0.71	0.33	0.50	0.77	0.26	0.41
ARCH -LM test (H_0 : no ARCH)	33.74	34.21	34.64	35.25	36.23	36.28	38.24
P-value of ARCH-LM test	0.052	0.08	0.10	0.11	0.11	0.14	0.24
Likelihood ratio (H_0 : no redundant variables)	0.12	0.01	0.49	0.08	1.18	0.08	1.39
P-value of Likelihood ratio test	0.73	0.93	0.48	0.77	0.23	0.77	0.244
Breusch-Godfrey Lagrange multiplier (LM) serial correlation test	2.09	2.02	2.03	2.07	2.00	2.10	1.99
P-value of Breusch-Godfrey LM test	0.22	0.26	0.20	0.23	0.19	0.18	0.21
SOUTH AFRICA							
Adjusted r-squared	0.53	0.56	0.59	0.59	0.58	0.55	0.52
F-statistic	7.40	11.61	10.69	10.98	10.24	10.34	9.84
P-value (F-statistic)	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ramsey test (H_0 : no omitted variables)	1.50	0.83	0.57	1.14	1.81	0.67	1.44
P-value of Ramsey test	0.14	0.41	0.56	0.25	0.07	0.5	0.15
ARCH-LM test (H_0 : no ARCH)	1.81	4.36	2.01	2.98	3.65	1.20	1.12
P-value of ARCH-LM test	0.17	0.11	0.18	0.37	0.39	0.27	0.29
Likelihood ratio (H_0 : no redundant variables)	2.77	2.75	1.74	0.11	1.73	0.23	0.21
P-value of Likelihood ratio test	0.10	0.09	0.18	0.75	0.19	0.63	0.65
Breusch-Godfrey Lagrange multiplier (LM) serial correlation test	1.99	2.01	2.02	2.01	2.01	2.04	2.04
P-value of Breusch-Godfrey LM test	0.17	0.22	0.19	0.18	0.25	0.24	0.23

The F-statistics for both countries are significant, indicating that the posited model aptly fits the underlying data. In tandem with the Ramsey model specification (omitted variables) and Likelihood ratio (redundant variables) test results, it may be inferred that the regression models have appropriate functional forms and are correctly specified. Additionally, the Breusch-Godfrey Lagrange multiplier (LM) serial correlation for both economies illustrates that there is no autocorrelation. This is reinforced by the Box-Pierce/Ljung-Box residual autocorrelation function correlograms (ACFs) graphed in the Appendix 1 and 2. The figures in Appendix 1 are for Ghana while those in Appendix 2 are for South Africa. The ACFs graphed for both countries indicate there is no serial correlation.

Tables 9 and 10 present results of regression coefficient homogeneity tests for Ghana and South Africa respectively. For both countries, the slope coefficients for each independent variable are distinct from each other and non-zero at each quantile.

5. Conclusion

This study investigates the interest rate-market return threshold relation in Ghana and South Africa. It also examines impact of interest rate volatility. To achieve its purposes, it develops a model with nonlinear independent variables, subsequently estimated by quantile regressions. The empirical evidence confirms there is an interest rate-return threshold, as suggested by macroeconomic theory. It further finds that interest rate volatility is critical for the JSE, the relatively more efficient stock market. Although the linear interest rate-return relation is vital, the study also emphasizes a nonlinear component and interactions between the considered variables. Such multi-dimensional effects are ignored when only linear models are considered.

The study, additionally, highlights that interest rate and its volatility are not equally critical in different stock markets. The study suggests that market inefficiency dampens sensitivity of stock returns to interest rate variations. Consequently, apart from establishing stock markets, SSA countries need to foster enhanced efficiency. As well, crowding out by government must be minimized in order to reduce interest rate risk. This is a concern as public debt is relatively high in Ghana (Bank of Ghana, 2015).

The findings of this study are critical for policymakers and other stakeholders. Keeping interest rates below the threshold may affect achieving inflation targets. The direct and indirect impacts of government actions and programs must be critically considered, in this regard. High interest rate uncertainty should also be discouraged with prudent economic policies. This is necessary as measures to deepen SSA stock markets are not impeded by unintended adverse policy consequences that raise interest rates beyond the threshold. This study, further, underscores the interaction between interest rate, its risk and market returns. It is hoped that the findings herein will stimulate further research.

Table 9: Quantile coefficient equality tests - Ghana

			VARIABLE: Interest rate				
QUANTILE	10th	25th	40th	50th	60th	75th	90t
10th							
25th	50.01**						
40th	10.64**	17.10**					
50th	60.24**	21.14**	69.78**				
60th	14.81**	59.87**	51.78**	51.36**			
75th	77.39**	16.75**	34.20**	34.20**	51.55**		
90th	16.10**	9.76**	53.44**	29.36**	49.88**	12.11*	
Homogeneity	141.03**						
			VARIABLE: Interest rate volatility				
10th							
25th	48.63**						
40th	50.97**	50.03**					
50th	34.52**	24.04**	20.24**				
60th	51.00**	15.76**	12.58**	42.04**			
75th	26.40**	13.61**	10.91**	50.19**	14.81**		
90th	19.22**	23.35**	18.58**	35.39**	65.49**	56.11*	
Homogeneity	11.81**						
			VARIABLE: Nonlinear interest				
10th							
25th	83.17**						
40th		*					
50th		*	*				
60th	**	*	*	*			
75th		*	*	*	*		
90th		*	*	*	*	26.72*	
Homogeneity	58.76**						
			VARIABLE: Interest rate-return interaction				
10th							
25th	85.50**						
40th	10.17**	36.88**					
50th	50.58**	29.10**	78.44**				
60th	13.68**	56.75**	16.80**	17.24**			
75th	60.83**	36.03**	34.20**	58.80**	88.74**		
90th	78.44**	66.00**	25.14**	48.74**	16.44**	40.43*	
Homogeneity	21.05**						
			VARIABLE: Interest volatility-return interaction				
10th							
25th	38.07**						
40th	90.56**	71.79**					
50th	20.41**	60.55**	56.65**				
60th	11.28**	70.89**	14.96**	49.57**			
75th	9.86**	18.90**	49.61**	16.94**	37.35**		
90th	87.79**	13.96**	18.75**	57.69**	11.58**	24.11*	
Homogeneity test	85.42**						

NOTE: ** and *** represent significance at the 5 and 1 percent levels respectively.

Table 10: Quantile coefficient equality tests – South Africa

QUANTIL	10th	25th	40th	50th	60th	75th	90t
			VARIABLE: Interest rate				
10th							
25th	80.81**						
40th	10.88**	37.97**					
50th	78.09**	35.77**	61.56**				
60th	15.70**	11.47**	15.76**	18.25**			
75th	39.07**	59.74**	10.81**	9.75**	27.63**		
90th	26.53**	23.04**	16.10**	24.86**	14.92**	21.53*	
Homogeneit	27.35**						
			VARIABLE: Interest rate volatility				
10th							
25th	15.79**						
40th	70.51**	11.82**					
50th	72.04**	12.26**	25.77**				
60th	10.98**	70.76**	12.41**	43.14**			
75th	14.12**	19.05**	18.43**	11.05**	11.82**		
90th	25.24**	18.72**	36.47**	47.39**	19.21**	14.43*	
Homogeneit	94.72**						
			VARIABLE: Nonlinear interest				
10th							
25th	20.56**						
40th	*	*					
50th	*	*	*				
60th	*	*	*	*			
75th	*	*	*	*	*		
90th	*	*	*	*	*	30.65*	
Homogeneit	22.64**						
			VARIABLE: Interest-return interaction				
10th							
25th	15.04						
40th	47.90	12.11					
50th	48.47	23.85	13.66				
60th	67.60	41.01	15.96	14.68			
75th	28.93	39.82	17.32	10.31	66.37		
90th	27.59	26.53	18.54	73.17	29.18	25.24	
Homogeneit	22.29						
			VARIABLE: Interest rate volatility-return interaction				
10th							
25th	76.49						
40th	43.48	14.23					
50th	40.68	13.09	20.82				
60th	42.89	13.45	10.74	10.51			
75th	45.00	29.14	29.85	30.37	30.33		
90th	10.84	64.85	60.59	23.77	28.43	29.18	
Homogeneit y test	41.08						

NOTE: ** and *** represent significance at the 5 and 1 percent levels respectively.

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APPENDIX I: Residual autocorrelation function (ACF) correlograms - Ghana

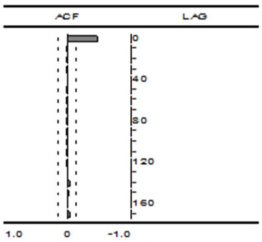


Figure 1. Quantile (0.1)

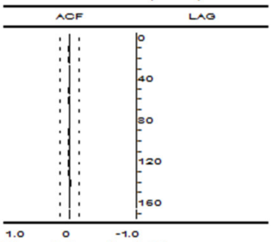


Figure 2 Quantile (0.25)

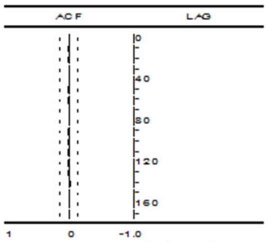


Figure 3. Quantile (0.40)

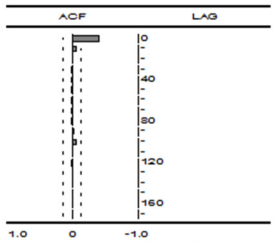


Figure 4. quantile (0.5)

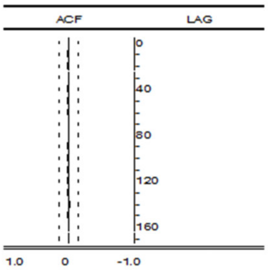


Figure 5. Quantile (0.60)

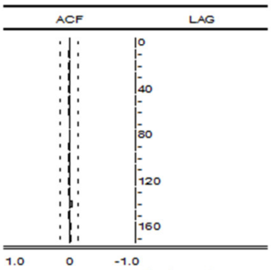


Figure 6. Quantile (0.75)

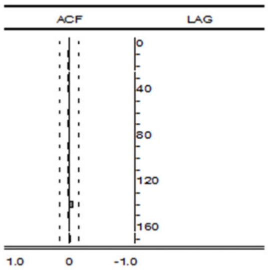


Figure 7. Quantile (0.90)

APPENDIX II: Residual autocorrelation function (ACF) correlograms – South Africa

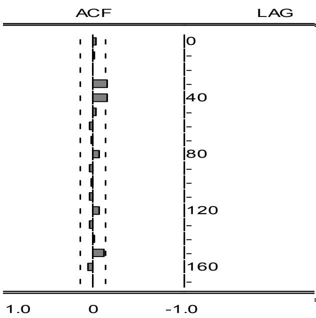


Figure 1. Quantile (0.1)

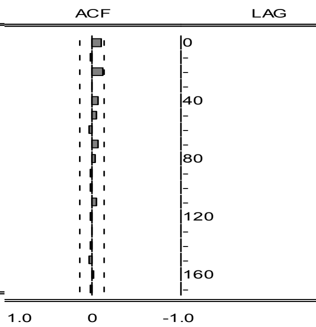


Figure 2 quantile (0.25)

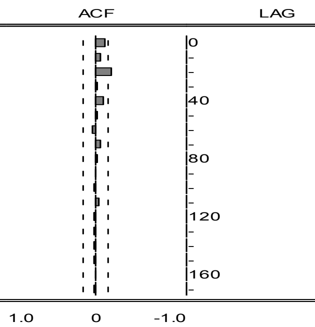
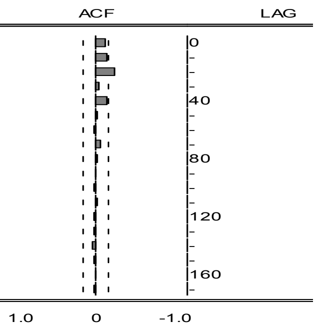


Figure 3. Quantile (0.40)



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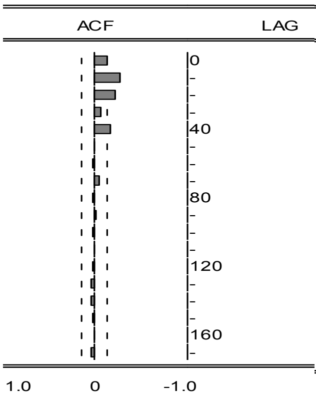

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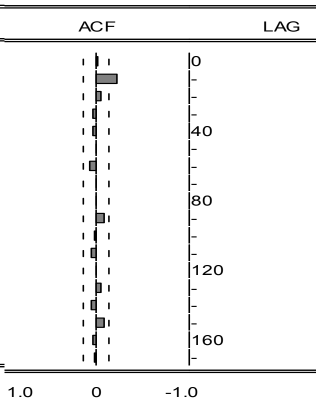

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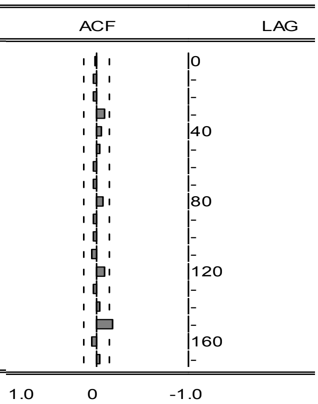

Figure 7. Quantile (0.90)